Prioritization of Louisiana Parishes based on Industrial Releases of Known or Suspected Carcinogens

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This investigation evaluated the geographic distribution of carcinogen releases by Louisiana industries to prioritize areas for regulatory oversight, research and monitoring, and to promote clinician awareness and vigilance. Data on estimated industry releases for the period between 1996 and 2011 were obtained from the US Environmental Protection Agency's Toxics Release Inventory. Chemicals associated with cancers of the prostate, lung, bladder, kidney, breast and non-Hodgkin lymphoma were identified. The Risk Screening Environmental Indicators model was used to derive measures or model scores based on chemical toxicity, fate and transport, and population characteristics. Parishes, chemicals, industries and media generating the highest model scores were identified. Parishes with the highest model scores were East Baton Rouge, Calcasieu, Caddo and St. John the Baptist. Clinicians should carefully monitor cancer cases in these areas, and if patients reside near or work in industry, an occupational and environmental history should be considered.

INTRODUCTION

In Louisiana, cancer incidence is significantly higher than the national rate for white men, black men and black women; and cancer mortality is significantly higher for blacks and whites of both sexes.[1] The reasons for these disparities are not fully understood,[1] but may include factors such as genetic predisposition, behavioral influences like smoking, access to medical care or early screening, and environmental hazard exposures. Environmental and occupational exposures have been estimated to contribute to only 6 percent of all cancer deaths in the US.[2] However, an accurate measure of the contribution of these factors to cancer risk is impossible, as the causes of cancer can be difficult to identify and may be multifactorial.[3-5] While there is little doubt that lifestyle factors such as smoking, physical inactivity, poor nutrition and obesity are the most important contributors to cancer when compared to environmental or occupational exposures, lower income workers and communities may have disproportionately higher exposures to occupational and environmental carcinogens.[6] Therefore, clinicians should be aware of the types of industrial hazards that may be present in their communities.

Most industries have been required to report toxic environmental releases to the US Environmental Protection Agency's (EPA) Toxics Release Inventory (TRI) Program since 1988. These facilities include those that meet the following conditions: 1) employ 10 or more full time workers; and 2) are in a specific industrial sector or are a federal facility; and 3) manufacture or process more than 25,000 pounds of a listed chemical or uses more than 10,000 pounds of a listed chemical in a given year.[7] Over 682 chemicals and chemical categories must be reported along with information describing the facility, the chemical released, the release amount and the media of release.[7] TRI data on chemical releases have proved useful to public health surveillance and research activities.[8-9] For example, areas with higher levels of TRI releases are significantly associated with higher mortality rates.[8] Areas with higher levels of TRI-reported carcinogen releases are associated with significantly higher hospitalization rates.[9] And a significantly increased risk of lung cancer incidence has been associated with TRI releases of chromium, formaldehyde and nickel.[10] Studies of this kind have been useful in generating hypotheses and stimulating research, but like all ecological studies, they are prone ecological fallacy. They merely demonstrate association, not causation, because of unmeasured and uncontrolled confounding factors.

Several studies have used TRI data to identify areas and populations facing the highest potential health risks from industrial releases.[11-13] Most previous studies have relied on quantity-based evaluations, but did not account for factors such as chemical toxicity, environmental fate and transport, or population proximity and characteristics. In 2004, Chakraborty[11] was one of the first researchers to incorporate Toxic Equivalency Potentials, a crude measure of potential harm based on toxicity and environmental fate, into a TRI-based screening study to identify states facing the highest potential carcinogenic and non-carcinogenic risk from industrial toxic releases. And in 2010, Lim *et al*[12] coupled TRI data with toxicity potentials to rank and prioritize chemicals, states and industries. Both of these nationwide studies identified Louisiana as one of the ten states with the highest potential cancer impact from TRI releases.

This investigation extends those two prior studies but narrows the focus to Louisiana parishes and bases the screening on a novel measure. The US EPA's Risk Screening Environmental Indicators (RSEI) model is used to derive chemical- and facility-specific scores. The RSEI model estimates a surrogate "dose" based on chemical-specific reported release quantities, pathway-specific modeling of the chemical fate and transport through the environment, and facility-specific population characteristics and exposure factors.[14-15] It then incorporates toxicity information to calculate a relative "risk" score for the entire population.[15] The RSEI-based score is not a true risk estimation- it is a unitless measure and is not independently meaningful. Rather, it is a relative measure that can be compared to other RSEI-based scores to compare and prioritize areas, chemicals and industries.[14] In this study, model scores were generated for groups of chemicals with known or suspected associations to specific cancers. Cancers of the prostate, lung, bladder, kidney, breast and non-Hodgkin lymphoma were selected on the basis of their high state incidence rates[1] and their association with environmental hazards in the literature. These cancer-specific scores were then used to prioritize parishes and industries. Rankings are intended to serve as a guide to direct local research or monitoring investigations, and promote clinician awareness and vigilance. It should be emphasized that the information provided here is for screening purposes only and must not be construed to imply any causal relationship between a release and an individual case of disease. Cancer incidence rates were not purposefully included to prevent unintended linkages with these derived scores, as that is not the objective of this analysis. Cancer incidence rates can be obtained from the Louisiana Tumor Registry's website.[1] The results highlighted serve only as a starting point for drawing attention to areas that have the potential for health impact due to industrial toxic releases.

MATERIALS AND METHODS

Environmental releases of carcinogens reported to the TRI Program between 1996 and 2011 were evaluated. Occupational Safety and Health Administration (OSHA) carcinogens and carcinogens associated with cancers of the prostate, lung, bladder, kidney and breast, and with non-Hodgkin lymphoma (NHL) were the focus of this investigation. Several sources were used to create a list of chemicals considered to be known or suspected carcinogens. These included the International Agency for Research on Cancer (IARC),[16] the EPA's Integrated Risk Screening Information System (IRIS),[17] the National Toxicology Program's 12th Report on Carcinogens,[18] and the OSHA Select Carcinogen list.[19] Table 1 presents the list of chemicals evaluated.

Technical information about the methodology and assumptions used in the RSEI model for calculating relative scores for releases and transfers to air and water are available online.[14] Release estimates (pounds), which are values directly reported to the TRI program based on facility calculations, were also obtained using the RSEI model. The sum of releases and model scores were derived for cancer-specific carcinogens by chemical, medium of release (only air and water releases were evaluated), industry (based on 2-digit primary standard industrial classification or code or SIC) and parish. Aggregate releases and model scores were then ranked to prioritize chemicals, media, industries and parishes.

RESULTS

Model scores were used to prioritize parishes releasing OSHA carcinogens, and carcinogens associated with cancers of the prostate, lung, bladder, kidney and breast, and non-Hodgkins lymphoma (NHL) (Table 2). Figure 1 presents the percent of parish contribution to the total state model score for cancer-specific carcinogens. Parishes consistently ranked as the highest contributors to statewide model scores included: Caddo, St. John the Baptist, East Baton Rouge and Calcasieu. These parishes were also along the highest contributors to statewide model scores for OSHA carcinogens.

Carcinogens contributing the greatest amounts to the total statewide cancer-specific model scores included: chromium, polycyclic aromatic compounds and 1,3-butadiene. Other high carcinogen contributors to the total model scores included: chloroprene, chloroform, trichloroethylene, benzene, and lead and lead compounds (Table 2). Many of these chemicals with the largest model scores were not among those with the largest releases (data not shown), highlighting the impact that other factors, such as chemical fate and transport, play in the potential for exposure and health impact.

Industries contributing the greatest amounts to the total statewide cancer-specific model scores included: chemicals and allied products, fabricated metal products, and petroleum refining and related industries (Table 2). In Calcasieu Parish, 99% of TRI-reporting facilities are industries within the categories of chemicals and allied products or petroleum refining and related industries. These industries also account for 99.6% of TRI-reporting facilities in East Baton Rouge Parish. In Caddo Parish, 'fabricated metal products' comprise about 99.5% of TRI-reporting facilities; and in St. John the Baptist Parish, 'chemicals and allied products' comprise about 99.6% of TRI-reporting facilities.

The media of release contributing the greatest to the total statewide model scores for most cancer-specific carcinogen groups were fugitive air emissions and point (or stack) air

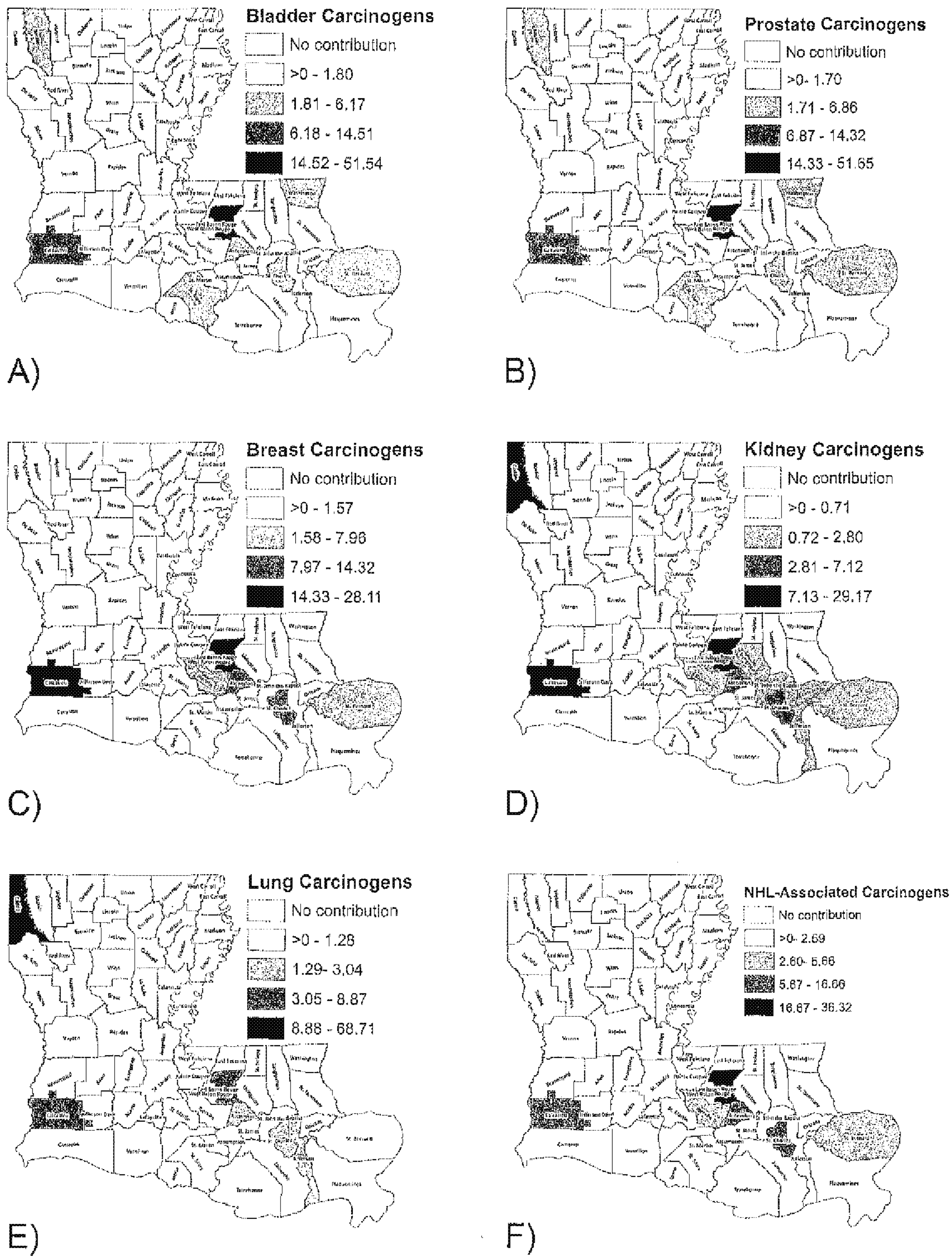
Table 1: List of cancer-specific carcinogens reported to the EPA's TRI Program and included in the evaluation

OSHA Carcinogens	OSHA Carcinogens (continued)	Breast-Associated Carcinogens	NHL-Associated Carcinogens	Kidney-Associated Carcinogens (continued)
1.1-Dimethyl Hydrazine	Diethyl sulfate	1.2-Dichloroethane	1.2-Dichloroethane	Tetrachloroethylene
1.2.3-Trichloropropane	Dimethyl sulfate	1.3-Butadiene	1.3-Butadiene	Trichloroethylene
1.2-Butylene oxide	Dioxane	Acetaldehyde	Acetaldehyde	**Bladder-Associated Carcinogens**
1.2-Dibromoethane	Dioxin and dioxin-like compounds	Benzene	Arsenic & arsenic compounds	Arsenic and arsenic compounds
1.2-Dichloroethane	Epichlorohydrin	Carbon tetrachloride	Benzene	Cadmium & Cd compounds
1.3-Butadiene	Ethyl acrylate	Dichloromethane	Cadmium & Cd compounds	Cadmium & Cd compounds
1.3-Dichloropropylene	Ethylbenzene	Dioxane	Carbon tetrachloride	Chloroform
2.4-Diaminotoluene	Ethylene oxide	Hydrazine	Formaldehyde	Creosote, coal tar
2.4-Dinitrotoluene	Formaldehyde	Nitrobenzene	Hexachlorobenzene	Dichlorobromomethane
2.6-Xylidine	Glycidol	Polychlorinated biphenyls (PCBs)	Lead and lead compounds	Lead and lead compounds
2-Nitropropane	Heptachlor	Propyleneimine	Polychlorinated biphenyl (PCBs)	Polycyclic aromatic compounds
4.4'-Methylenedianiline	Hexachlorobenzene	Styrene	Polycyclic aromatic compounds	Tetrachloroethylene
4-Aminoazobenzene	Hexachloroethane	Toluenediisocyanate	Styrene	
4-Aminodiphenyl	Lead and lead compounds	**Lung-Associated Carcinogens**	Tetrachloroethylene	
Acetaldehyde	Naphthalene	1.2-Dichloroethane	Trichloroethylene	
Acetamide	Nickel and nickel compounds	1.3-Butadiene	**Prostate-Assoc. Carcinogens**	
Acrylamide	Nitrilotriacetic acid	Acetaldehyde	Arsenic & arsenic compounds	
Acrylonitrile	Nitrobenzene	Acrylamide	Cadmium & Cd compounds	
Arsenic and arsenic compounds	Nitromethane	Acrylonitrile	Creosote, coal tar	
Asbestos (friable)	o-Toluidine	Arsenic and arsenic compounds	Dichloromethane	
Benzene	Pentachlorophenol	Benzene	Dioxin & dioxin-like compounds	
Beryllium and beryllium compounds	Polychlorinated biphenyls	Cadmium & Cd compounds	Polycyclic aromatic compounds	
Cadmium and cadmium compounds	Polycyclic aromatic compounds	Chromium & Cr compounds	Trichloroethylene	
Carbon tetrachloride	Propylene oxide	Creosote, coal tar	**Kidney-Associated Carcinogens**	
Catechol	Propyleneimine	Dichloromethane	1.3-Butadiene	
Chlordane	Styrene	Dioxin and dioxin-like compounds	1.4-Dichlorobenzene	
Chloroform	Styrene oxide	Epichlorohydrin	Acrylamide	
Chloroprene	Tetrachloroethylene	Ethylene oxide	Arsenic and arsenic compounds	
Chromium and chromium compounds	Toluene-2.4-diisocyanate	Formaldehyde	Cadmium & Cd compounds	
Cobalt and cobalt compounds	Toluenediisocyanate	Hydrazine	Chloroform	
Creosote, coal tar	Toxaphene	Lead and lead compounds	Creosote, coal tar	
Di(2-ethylhexyl) phthalate	trans-1.3-Dichloropropene	Nickel and nickel compounds	Dichloromethane	
Di(2-ethylhexyl) phthalate	Trichloroethylene	Nitrobenzene	Dioxane	
Diaminotoluene (mixed isomers)	Urethane (Ethyl carbamate)	Polychlorinated biphenyls (PCBs)	Dioxin & dioxin-like compounds	
Dichlorobenzene (mixed isomers)	Vinyl acetate	Polycyclic aromatic compounds	Hexachlorobenzene	
Dichlorobromomethane	Vinyl bromide	Styrene	Lead and lead compounds	
Dichloromethane	Vinyl chloride	Sulfuric acid	Nickel and nickel compounds	

Table 2: Top contributors to total model scores (% of contribution to total score)

	OSHA carcinogens	Bladder carcinogens	Prostate carcinogens	Breast carcinogens	Kidney carcinogens	Lung carcinogens	NHL-associated carcinogens
Parishes	Caddo (43%)[1]	East Baton Rouge (52%)[3]	East Baton Rouge (52%)[5]	Calcasieu (28%)[7]	East Baton Rouge (29%)[9]	Caddo (69%)[11]	East Baton Rouge (36%)[13]
	St. John the Baptist (24%)[2]	Calcasieu (15%)[4]	Calcasieu (14%)[6]	East Baton Rouge (23%)[8]	Calcasieu (22%)[10]	East Baton Rouge (9%)[12]	Calcasieu (17%)[14]
Chemicals	Chromium and chromium compounds (44%)	Polycyclic aromatic compounds (84%)	Polycyclic aromatic compounds (94%)	1,3-Butadiene (23%)	1,3-Butadiene (42%)	Chromium and chromium compounds (71%)	Polycyclic aromatic compounds (35%)
	Chloroprene (24%)	Chloroform (12%)	Trichloroethylene (3%)	Benzene (23%)	Lead and lead compounds (28%)	Polycyclic aromatic compounds (7%)	1,3-Butadiene (16%)
Industries	Chemicals and allied products (71%)	Chemicals and allied products (61%)	Chemicals and allied products (57%)	Chemicals and allied products (75%)	Chemicals and allied products (48%)	Fabricated metal products (70%)	Chemicals and allied products (66%)
	Fabricated metal products (2%)	Petroleum refining and related industries (27%)	Petroleum refining and related industries (31%)	Petroleum refining and related industries (18%)	Fabricated metal products (24%)	Chemicals and allied products (17%)	Petroleum refining and related industries (25%)
Media	Fugitive air emissions (59%)	Direct water releases (53%)	Direct water releases (53%)	Fugitive air emissions (58%)	Fugitive air emissions (89%)	Fugitive air emissions (83%)	Fugitive air emissions (43%)
	Point (stack) air emissions (37%)	Fugitive air emissions (23%)	Fugitive air emissions (23%)	Point (stack) air emissions (39%)	Point (stack) air emissions (10%)	Point (stack) air emissions (12%)	Point (stack) air emissions (33%)

Figure 1: Percent of parish contribution to total statewide model score for cancer-specific carcinogens (based on 1996-2011 TRI-reported data and RSEI-generated scores).



Note: Data are displayed using the Jenks Optimization (Natural Breaks) method of classification emissions. However, for bladder and prostate carcinogens, direct water releases were a primary contributor to total statewide model scores, and fugitive air emissions were a secondary contributor (Table 2).

DISCUSSION

According to Louisiana's Division of Administration, Louisiana "has the greatest concentration of crude oil refineries, natural gas processing plants and petrochemical facilities in the Western Hemisphere".[20] In addition, "Louisiana produces 25 percent of the nation's petrochemicals"; is the third largest producer and refiner of petroleum; and has "more than 100 major chemical plants " producing "chemicals, fertilizers and plastics, plus the feedstocks for a wide array of other products". [20] Many of the parishes identified in this investigation are consistently ranked as top contributors to the model scores (Figure 1). This is to be expected as they are among the most heavily industrialized areas of the state. With the exception of St. John the Baptist Parish, each identified parish has over 25 TRI-reporting facilities: Calcaiseu has 42 facilities (8% of the state's TRI-reporting facilities), East Baton Rouge has 40 facilities (7%), and Caddo has 26 facilities (5%), while St. John the Baptist has only 13 facilities (2%). Given the extent of industrial activities in the state, awareness of the distribution of potential hazards is essential in order to both recognize and prevent diseases associated with occupational and environmental exposures.

It is the intent of the author to motivate clinicians, especially environmental and occupational health professionals, to investigate the RSEI model for the purpose of screening their communities for potential hazards caused by industrial releases. The RSEI model allows those who want to evaluate the potential impact of TRI releases, to screen locations and facilities based on a measure which incorporates exposure and toxicity factors. The RSEI models exposure pathways for stack and fugitive air emissions, direct surface water releases, transfers to publically owned treatment works, off site transfers and on-site land releases; and calculates risk-related results for air and surface water pathways.[15] The models, parameters, algorithms and assumptions used to estimate exposure are too lengthy to list here, but are described in detail in EPA's technical documentation.[15] As with all models, results are based on simplified inputs, such as those measuring toxicity, environmental fate and transport, and potential exposure. Air pathways were modeled using the American Meteorological Society/EPA Regulatory Model (AERMOD)- a steady state Gaussian plume model used to estimate pollutant concentrations downwind of a stack or area source. Facility-specific parameters, meteorology and chemical-specific first order decay rates are used. Surface water pathways are modeled by estimating contaminant concentrations in drinking water and fish, where a public water system's intake is located in a stream path of the release. Some data used in surface water models include EPA's records of discharge permits, decay coefficients, estimates of water velocity, public water system distribution details from EPA's Safe Drinking Water Information System and chemical-specific bioconcentration factors. [15] The sources for exposure factors, toxicity weights and demographics are the EPA's Exposure Factors Handbook,[21] EPA's Integrated Risk Information System,[17] and the US Census data, respectively. As stated in EPA's RSEI methodology document, [15] "The exposure algorithms are intended to be simple ways to gauge relative risks from releases to different media in a consistent, defensible way, by modeling and estimating exposure. In some cases, the modeling is purposely simplified, given the lack of site-specific data". In short, the RSEI is a free and simple to use model that can assist clinicians in local investigations, when the causal factor of a disease is unknown, or when environmental exposure factors are suspected.

Results presented are subject to several limitations due to the availability and quality of model inputs and model assumptions. For example, not all sources of carcinogens are included in this analysis- mobile sources and industries under the reporting threshold are not represented; and some carcinogens are not reported to the TRI Program. Also, model scores could not be generated for chemicals lacking information required for modeling, such as measures of toxicity. Probably the greatest limitation is that industry-reported TRI data are hard to verify and may be prone to biased reporting. One cannot exclude the possibility that industries under-report actual releases to meet regulatory requirements. Results should also be put into the proper context. That is, this analysis does not consider chemicals that people are exposed to on a more common basis. Toxicants can be found in vehicle exhaust, processed food, air fresheners, pesticides, paints and varnishes, and cleaning products, just to name a few sources. It is estimated that the average American spends 90 percent of their time indoors. Indoor pollutant levels may be two to five times higher than outdoor pollutant levels.[22] Thus, the RSEI model is most suitable for use by environmental and occupational clinicians to identify and screen potential hazards to workers and members of fenceline communities.

CONCLUSIONS

Caddo, St. John the Baptist, East Baton Rouge and Calcasieu parishes were consistently ranked as the highest contributors to cancer-specific model scores. Clinicians should be cognizant of industrial hazards in their communities, and conduct environmental and occupational histories of patients in fenceline communities or in industrial occupations. The RSEI model is an easy to use method for screening potential industry-related hazards at the parish or neighborhood level; and is relevant to doctors serving industry workers and fenceline communities. It is intended that the results presented here will guide and influence state monitoring efforts, regulatory oversight, health investigations, and clinician awareness.

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